



September 18, 2015

Via Electronic Filing

Marlene H. Dortch, Secretary
Federal Communications Commission
445 Twelfth Street, SW
Washington, DC 20554

Re: Written ex parte presentation, GN Docket No. 14-177

Dear Ms. Dortch:

Mobile Future respectfully submits to the Commission the attached paper, “Mobilizing America: Accelerating Next Generation Wireless Opportunities Everywhere,” written for Mobile Future by Jim Kohlenberger, President of JK Strategies and former Chief of Staff in the White House Office of Science and Technology Policy. The paper examines the power and promise of 5G technology and puts forward a comprehensive strategy to “Mobilize America” in order to ensure continued U.S. global leadership in the next generation wireless revolution.

While the exact technologies that will enable 5G have yet to be specifically defined, the report outlines “The Five G’s of 5G,” which characterize the next generation of wireless:

- **G**igabit speeds that enable data rates of 10Gbps or higher;
- **G**igahertz frequencies capable of using spectrum above 6 GHz;
- **G**reater flexibility to enable networks to rapidly adapt to a broader range of demands;
- **G**ee-whiz gadgets that are connected, intelligent and able to anticipate our needs; and
- **G**lobal competition as 5G leaders drive opportunity and reap its many rewards.

The report emphasizes that as mobile broadband becomes the predominant communications platform of our time, and serves as the global backbone expanding Internet of Things, the next wireless revolution will need to be about more than blazing fast speeds. There is an urgent need for network technology that can support billions of simultaneously connected devices, as well as provide quicker reaction times, exceptional network reliability, and the ability to switch between spectrum bands and networks without delay.

The report details that a comprehensive strategy to “Mobilize America” must:

- *Address our nation's toughest challenges.* Reducing barriers to wireless-led innovation can help accelerate breakthrough solutions aimed at achieving major national objectives – from reducing greenhouse gas emissions, to improving automobile safety, to revolutionizing health care.
- *Accelerate access to vital spectrum.* Since it can take as long as seven years to free up a single spectrum band, and the U.S. currently has no national plan for identifying spectrum beyond 2020, policymakers must develop a long-term strategy for maximizing the national benefits that can come from pursuing increasingly scarce spectrum and making it available to support rapidly expanding wireless connectivity.
- *Lower barriers for mobile innovation and investment.* World-leading wireless networks require massive private sector investment—\$32 billion last year in the United States alone. Ensuring a policy environment that is consistent and constructive in encouraging this formidable competitive advantage for our nation is essential.
- *Crank up the R&D innovation engine.* While our global rivals invest billions in 5G research, overall U.S. federal spending on research and development as a share of total government outlays has fallen from nearly 10 percent during the height of the space race in 1968 to just 3 percent in 2015. We must do better.
- *Fill the talent pipeline.* Creating opportunities for American workers to receive the training and education they need to participate in a 5G economy will accelerate job growth—and our nation's wireless innovation leadership.

While 5G networks are unlikely to be deployed in the near future, the paper stresses that the global race to lead the world in this next wireless frontier is already well underway. Swift, bold action is required to develop a comprehensive national strategy for ensuring U.S. leadership in the transition from 4G to 5G.

Pursuant to Section 1.1206 of the Commission's rules, a copy of this letter is being filed via ECFS with your office. Please do not hesitate to contact the undersigned with any questions.

Respectfully submitted,

/s/ Jonathan Spalter
Jonathan Spalter, Chair
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Attachment

Mobilizing America:

**Accelerating Next Generation Wireless
Opportunities Everywhere**

Jim Kohlenberger

September 8, 2015



Mobilizing America

Accelerating next generation wireless opportunities everywhere

*Not just blazing fast speeds, but smarter networks enabling smarter devices
and transformative new opportunities*

Executive Summary

Thanks to pragmatic policy choices, a vibrant innovation ecosystem and massive private sector investment, the U.S. leads the mobile world today with an estimated half of all 4G LTE connections on earth. Yet a heated global race already is underway to claim the next-generation 5G crown. Ubiquitous, advanced mobility is central to our future competitiveness and national prosperity. It has now become imperative that the United States begin to develop a comprehensive strategy to “Mobilize America” in order to ensure continued U.S. leadership of an increasingly connected, capable and transformational wireless world.

Mobile broadband has become a vital enabler of economic gains and personal opportunity. Our global competitors understand the power of mobile innovation and are aggressively working to surpass the U.S. Europe, for example, has initiated a 5G public-private partnership aimed at leading the world in this next wireless frontier. South Korea plans to launch a 5G trial network when it hosts the 2018 Winter Olympic Games, and Japan aims to follow suit at the 2020 Summer Olympic Games in Tokyo. China, too, has established an interagency “promotion group” to coordinate 5G activities among industry and academia.

While the exact technologies that will enable 5G have yet to be specifically defined, we know directionally where it is headed—forward. Here’s what we call “The Five G’s of 5G,” which characterize the quantum leap ahead.

- **G**igabit speeds that enable data rates of 10Gbps or higher;
- **G**igahertz frequencies capable of using spectrum above 6 GHz;
- **G**reater flexibility to enable networks to rapidly adapt to a broader range of demands;
- **G**ee-whiz gadgets that are connected, intelligent and able to anticipate our needs; and
- **G**lobal competition as 5G leaders drives opportunity and reaps its many rewards.

The next wireless revolution is about far more than connecting our phones to faster speeds. Our homes, cars and countless other physical tools will become sentient, transforming whole sectors of our economy—from transportation and energy to health care and manufacturing—as the 5G world connects virtually any and every “thing.”

Realizing the full potential of these opportunities will require networks that:

- Offer speeds 100 times faster than today;

- Support billions of simultaneously connected devices;
- React 10 times more quickly, enabling sub-millisecond latencies to control things like autonomous vehicles with more precision and real-time connected controls;
- Enable high-performance applications with exceptional network reliability;
- Seamlessly switch between spectrum bands and networks on the fly; and
- Reduce energy-per-bit power consumption by a factor of 1,000.

As this smart revolution ripples throughout our economy and our lives, smarter wireless policy becomes even more vital. Thus, a comprehensive strategy to Mobilize America must:

- *Address our nation's toughest challenges.* Reducing barriers to wireless-led innovation can help accelerate breakthrough solutions aimed at achieving major national objectives – from reducing greenhouse gas emissions, to improving automobile safety, to revolutionizing health care.
- *Accelerate access to vital spectrum.* Since it can take as long as seven years to free up a single spectrum band, and the U.S. currently has no national plan for identifying spectrum beyond 2020, policymakers must develop a long-term strategy for maximizing the national benefits that can come from pursuing increasingly scarce spectrum and making it available to support rapidly expanding wireless connectivity.
- *Lower barriers for mobile innovation and investment.* World-leading wireless networks require massive private sector investment—\$32 billion last year in the United States alone. Ensuring a policy environment that is consistent and constructive in encouraging this formidable competitive advantage for our nation is essential.
- *Crank up the R&D innovation engine.* While our global rivals invest billions in 5G research, overall U.S. federal spending on research and development as a share of total government outlays has fallen from nearly 10 percent during the height of the space race in 1968 to just 3 percent in 2015. We must do better.
- *Fill the talent pipeline.* There are roughly half a million U.S. job openings that have not been filled in information technology fields like software development, network administration and cybersecurity. Creating opportunities for American workers to receive the training and education they need to participate in a 5G economy will accelerate job growth—and our nation's wireless innovation leadership.

Just as the United States came together behind a National Broadband Plan in 2010, so must our country unite again to lead the world into the next wireless frontier. Our 4G momentum alone will not carry us through. Global economic rivals have already left the starting gate in this next innovation race. The United States must move quickly and decisively to pull ahead. By acting now to develop and aggressively pursue a new national innovation plan—one aimed at mobilizing America—the U.S. can be on track to not only *participate* in the many opportunities of the 5G future, but to shape its direction and help lead the world in realizing its full potential.

Introduction

At a time when mobile broadband is quickly becoming the predominant communications platform of our time, what are the pragmatic policy choices for unleashing the massive new opportunities that the next generation of wireless innovation can deliver? As other countries around the globe race to beat us in the next generation wireless frontier called 5G, what can we do to advance U.S. leadership in wireless and accelerate the benefits that mobile broadband can deliver? If we are to unlock the blazing fast speeds and transformative new opportunities on the way to our 5G future, these are the fundamental question that policymakers need to answer.

When the very first wireless phone call was made, people called it revolutionary. Since then, it's been followed by several revolutionary new generations of wireless technology – each one more transformative than the next, and each one further accelerating the innovation that expands what we as humans are able to do with these modern mobile marvels. The first generation or 1G phones allowed us to, for the first time, talk with others while on the go. Second generation or 2G phones brought us text messaging and digital communications. 3G phones brought us the Internet and opened the door to the smart phone revolution.

Today we are in the midst of the 4G wireless revolution which is once again transforming everything about communications. Thanks to pragmatic policy choices, a vibrant innovation ecosystem and massive private investments in state of the art networks, today the U.S. leads the world in 4G deployment with an estimated 40 percent of all global 4G LTE connections.¹ It's been the proverbial goose that laid the golden egg – creating jobs, opportunities, an app economy, and enabling us to do things never before thought possible. Fortunately with innovative new technologies just over the horizon with the ability to further expand the power of wireless, we are just at the beginning of what may be possible.

However, the U.S. hasn't always led the mobile revolution², and ensuring that we continue to out-compete other countries depends on our ability to help foster a bright wireless future and the innovation that enables it. Around the globe Europe, China, Japan, South Korea and many others understand the power of mobile innovation and are moving aggressively to surpass the U.S. in the race for global 5G leadership. At this important juncture, when mobile broadband has become one of the most transformative technologies of our generation and a primary enabler of economic gains and personal opportunity, we can neither rest on our laurels nor lead merely through inertia. We need pragmatic and sustained US leadership to maintain our nation's pole position in wireless innovation – not just because we want to be first in the world in one of the primary technology drivers of our generation, but because we need to be wireless leaders so that we can harness mobile solutions to help solve some of the nation's most pressing challenges.

In the midst of today's 4G revolution, the pace of change in wireless makes it imperative that we quickly begin charting a winning 5G policy path by outlining our aspirations for 5G wireless innovation – what we want from it, what it can achieve, how it can help solve broader policy

challenges, the barriers we must remove to do so, and the building blocks that need to be put in place today to help us lead the world tomorrow.

So what is 5g?

Technically, 5G stands for the fifth-generation wireless technology. But what does 5G really mean? Federal Communications Commission Chairman Tom Wheeler has likened 5G to a Picasso painting where everyone who looks at 5G sees something slightly different. While the exact technologies that will enable 5G have yet to be specifically defined, we know directionally where it is headed—forward. And we know what it will do to our innovation ecosystem – accelerate it. In broad strokes, we also know what this will do – further fuel the powerful mobile engine of economic growth and opportunity at the heart of the digital revolution.

5G technologies will enable us to do amazing things with our phones – like streaming ultra high definition movies which are 16 times clearer than traditional HD movies,³ or downloading a 3D movie in about 6 seconds compared to about 6 minutes over today's 4G networks. However, 5G is not just about blazing fast speeds to download high definition movies faster. The next generation of wireless will enable whole new classes of technologies – the things we will not be able to live without, that connect us to and put us in charge of the physical world around us, and help usher in a new era that can literally mobilize America.

5G will enable networks that are:

- fast enough for real-time two-way high definition video
- swift enough to enable vehicle to vehicle collision avoidance faster than humans can react
- robust enough so that we can control large industrial machines in mission critical applications without fear of packet loss – a situation in which data is discarded because networks become overloaded
- dense enough to handle millions of simultaneous connections, and
- agile enough to connect a multitude of new types of devices that enable us to do entirely new things

Mobile innovation matters

Mobility is now a central driver of opportunity in our daily lives. Today's mobile innovations are putting power in consumers' hands and the world at their fingertips. Smartphones have become an essential resource and central hub for our technological lives. It's why we now buy more mobile devices than PCs. It's why 87% of millennials say their smartphones never leaves their side – night or day. It's why we reach for our smart phones more than 150 times a day. It's why we've now downloaded more than 100 billion apps that can do almost anything. It's why American's have an insatiable appetite for consuming more and more data on our phones – increasing usage by 120% between 2012 and 2013 alone. And it's why we know we are just at the beginning of this powerful revolution.

Mobility is an engine for economic growth. Mobile technologies now generate roughly 3.2 percent of U.S. GDP, and support more than 1.3 million jobs. These jobs that pay on average 65 percent more than other private sector jobs. The apps economy, which barely existed just five years ago, has earned developers more than \$30 billion, and now accounts for more than 750,000 jobs. It's clear that for the economy, mobile broadband is a job force multiplier a breakthrough technology with the ability to re-shape entire industries, and a vital infrastructure for the 21st century.

Mobile innovation is at the heart of this mobile ecosystem. The mobile technologies that are driving consumer and economic gains are built upon state of the art mobile networks. Getting here has taken innovations on a grand scale, some of the smartest minds in the world, and massive network investments to build out the 4G infrastructure. For today's networks, wireless network providers have already invested \$260 billion in their mobile infrastructure over the last decade-- \$32 billion in just the last year. These investments help make your wireless networks go faster and farther, and support the multitude of innovative new smartphones making their way to purses and pockets every year.

The Global Race for 5G Leadership is Already Underway

5G won't just be better, faster and cheaper, it will enable new consumer opportunities, technologies that can't even be imagined today, and new business models that reshape the way we think about communications. That is why so many countries around the world aren't just looking at 5G rollout as a new technological platform, but as an economic development platform to advance a more prosperous and productive future.

"Europe and Asia look at our 4G success with envy and are working hard to leapfrog the United States and take the lead in the next generation of wireless known as 5G."

-- Senator John Thune

- **Europe.** While 4G networks are just taking off there, European leaders are already taking bold steps in an effort to try and regain their wireless leadership.⁴ Leaders in Europe have initiated a 5G Public Private Partnership (PPP) and are investing about \$1.8 billion in 5G (both public and private dollars) in an effort to lead the world in the next wireless frontier on 5G and all of the technologies that go with it.⁵ As former European Commissioner Neelie Kroes, puts it, "OK, we missed 4G, we were the leader in 3G, now let's take over the 5G."⁶

"America's future competitiveness and global technology leadership depend, in part, upon the availability of additional spectrum. The world is going wireless, and we must not fall behind."

-- President Barack Obama

- **South Korea.** South Korea is already taking big steps with hopes of extending its wireless leadership into the 5G world through a comprehensive strategy. It has established a 5G Forum to conduct R&D, developed a universal infrastructure strategy, and established a national 5G implementation strategy. As a part of this effort it has committed \$1.5 billion to its "5G Creative Mobile Strategy."⁷ And to demonstrate its 5G leadership on the global stage, South Korea has plans to launch a 5G trial network for the Winter Olympic Games in 2018 – attempting to take away a gold medal for the first prototype network deployed in the world.
- **Japan.** Not far behind Korea, Japan intends to demonstrate its 5G leadership by launching a 5G trial network when the world has its eyes on Japan during the Summer Olympic Games in 2020 in Tokyo.
- **China.** With more mobile phones in use than any other country⁸, China has established an interagency "promotion group" to coordinate 5G activities in Chinese industry and academia in order to enter the 5G era in 2020.⁹

- **Finland.** Finland has already started building its first 5G test network in the northern city of Oulu. In addition to testing 5G technologies, the 5G Test Network (5GTN) will also help their domestic companies get a leg up on 5G application development as they are able to use the platform to test and build new early stage applications and to gain better understanding of the real-world benefits of 5G.¹⁰
- **Russia.** Even Russia hopes to get in the game with similar intentions to deploy a trial 5G network in time for the 2018 FIFA World Cup, which the country will host.¹¹

A U.S. Strategy for Mobilizing America

It should be no surprise that nations often are choosing global sporting events, where countries are trying to out-compete each other on the world stage, to demonstrate that they are out-competing the world on next generation mobile infrastructure. However what may be surprising is that there is no formal U.S. 5G initiative, or wireless focused policy initiative beyond 2020.¹² While policymakers have taken important steps to help the U.S. be the global leader in 4G deployment,¹³ it's now time to take the initiative to secure our ability to leverage our 4G success for future 5G leadership.

In 2011, the President challenged the public and private sector to work together to expand wireless access and set the ambitious goal of providing 4G mobile broadband to at least 98 percent of Americans.¹⁴ Thanks to proactive policy leadership, massive private sector network investment and the talent and tenacity of U.S. innovators, Americans are benefiting from a strategy that unleashed unprecedented wireless innovation, reduced the deficit by billions and achieved the President's 4G goal two years ahead of schedule.¹⁵

To extend this mobile legacy into the future, and assure that America leads the world in the next generation wireless technologies, policymakers need to:

- 1) **fulfill the goal of doubling the amount of commercially available mobile spectrum,¹⁶**
- 2) **launch a comprehensive strategy to further mobilize the nation and demonstrate America's continued leadership in the cutting edge technologies being unlocked by 4G and 5G through 2020 and beyond, and**
- 3) **harness emerging mobile broadband advances to help solve some of our most pressing challenges from improving public health to boosting productivity to reducing greenhouse emissions.**

Ubiquitous, advanced mobility is central to our future competitiveness and national prosperity. We need to act now to develop a comprehensive strategy to "Mobilize America" to ensure continued U.S. leadership for a bright mobile future. This strategy needs to focus on putting more spectrum bands into the spectrum pipeline, lowering the barriers for mobile startups, cranking up the

innovation engine through foundational R&D investments, filling the talent pipeline so that we have the most capable workforce and fostering policies that enable the expansion of high speed wireless networks.

The move to 5G will be more than just a step change. As we've moved from 1G to 4G technologies, the power of the phone has more than just multiplied. Each generation shift has exponentially increased the power in our hands, and the benefits to the economy. However unlike the past transitions from 1G to 2G to 3G, the 5G transition will be different. Previous transitions were driven by specific changes in technology that enabled greater opportunities. This time, however, 5G is not just a technological shift, it's a major paradigm shift in the way we think about mobile networks. This transition will bring together a number of critical technologies, a number of different wireless technologies and bands, to help enable simultaneous use of different wireless pathways to deliver something even more powerful than ever before. It means that our wireless future is about combining both evolutionary, and revolutionary technological change. It means that 5G is not a destination, it's a pathway of opportunities that extends from the 4G networks of today to the 5G networks of tomorrow.

While 5G networks are unlikely to be developed and deployed in any substantial ways in the U.S. or globally until the end of the decade at the earliest, what we do today lays the foundation for this future. Because 5G networks will be built upon our 4G networks, it means the best way to lead in 5G is to continue to lead in 4G. Our ability to out-innovate, out-invest and out-deploy a robust 4G infrastructure, will give us a boost in the 5G race. Thus to catapult us forward and better prepare us for 5G leadership, we will need to develop a near-term U.S. policy strategy that takes advantage of our existing world-class 4G networks. This strategy needs to focus on enabling future 4G technological upgrades, spectrum improvements, and necessary infrastructure investments that will enable us to continue to lead the world in 4G while creating the vital foundation for 5G networks. An advanced and robust 4G strategy will enable us to deploy 5G precursor technologies sooner and 5G networks faster once the technology becomes commercially available.

Harnessing mobile innovation can help solve pressing policy challenges

However, network deployment alone shouldn't be the sole focus of a national policy strategy. With the right conditions, 5G network improvements will unleash a new wave of opportunity as smart devices move from the palm of our hands to the physical world around us. Connecting more of the physical world to the Internet puts more power in our hands and allows us more control of the world around us. By the end of this decade, as many as 50 billion devices will be connected¹⁷ – our homes, cars, watches, and countless other physical tools will be sentient and connected and able to anticipate our needs. That's why this next wireless revolution is about far more than connecting our phones with faster speeds, or connecting billions of new kinds of devices to the Internet.

We have all seen how powerful the Internet has been – creating as much economic growth in the last 15 years as the industrial age did in 50 years. But as we connect the mobile Internet to the physical world around us, the technologies will become more transformative, producing opportunities that

are more pervasive, with impacts that are more profound. Think about it this way. The Internet has already transformed about 20 percent of our lives and about 20 percent of our economy – sectors from finance to entertainment have already been transformed by the Internet and digital technologies.¹⁸ It represents a significant accomplishment that has driven huge benefits. However, it also means that the remaining 80 percent of the economy is just waiting to be transformed. As we expand what mobile broadband can achieve, sectors like transportation, energy, health care, education, and manufacturing are poised to be transformed by connecting anything and everything that can be.

What's the scale of the coming transformation?

Consider this one fact: today, it's estimated that just one percent of the things that can be connected have been connected.¹⁹ The next big thing could be connecting lots of little things. GE is betting big on this revolution. GE estimates that by adding low cost connected devices to the machines in every industrial sector, we can boost efficiencies by as much as one percent.²⁰

For example, in the health care sector, remote patient monitoring using mobile devices is forecast to save the U.S. \$36 billion in health care costs by 2018 through small improvements that increase monitoring, and adherence to prescribed treatments and medicines.²¹ Similarly, take the typical UPS truck, which is now tracked by hundreds of sensors monitoring everything from when our packages arrive to how the engine is performing to predict maintenance issues, and how safely the driver is performing.²² UPS estimates that as they connect these sensors on their 40,000 trucks, if every driver can save just one minute per day the company can save as much as \$14 million over the course of a year.

These one percent improvements may seem small, but when added up it can drive gains that can transform entire sectors – helping us save time, fuel and even lives. These little gains add up to big wins. As we saw in the late '90s, just a one

"[The] United States should develop a strategy to incentivize the development of the Internet of Things in a way that maximizes the promise connected technologies hold to empower consumers, foster future economic growth, and improve our collective social well-being"

-- Unanimously adopted Senate Resolution

"Expanded wireless broadband access will trigger the creation of innovative new businesses, provide cost-effective connections in rural areas, increase productivity, improve public safety, and allow for the development of mobile telemedicine, telework, distance learning, and other new applications that will transform Americans' lives."

-- President Barack Obama

percent increase in Internet driven productivity growth helped boost the economy, create millions of jobs and lift standards of living.

Productivity growth is essential for sustaining middle-class incomes.²³ With just a similar one percent boost in productivity, GE estimates it could add about \$15 trillion to global GDP by 2030.²⁴ That's the equivalent of adding another U.S. economy to the global economy.

It means that mobile innovation and connected devices are now poised to deliver new gains in sectors that have traditionally not fully benefitted from technologically driven productivity improvements— from agriculture to health; from transportation to education; and from energy to finance. If policies are in place that enable the right technologies and ensure they are deployed in strategic ways, these connected devices can also help us solve some of our toughest policy challenges – from reducing greenhouse gas emissions, improving automobile safety and revolutionizing health care.

We can already see what may be possible as innovators in garages and laboratories across America start asking important questions about ways to leverage mobile innovation to achieve broader gains.

For example:

- **Helping Americans live longer, healthier lives.** As populations age and health care costs rise, what if we could harness next generation mobile technologies to improve health monitoring to better understand diseases²⁵, lower health costs by as much as \$36 billion²⁶, diagnose faster,²⁷ personalize medicine, revolutionize medical research²⁸, improve fitness²⁹ and help people live longer healthier lives?
- **Driving transportation gains that can save time, money, fuel and lives.** At a time of ever increasing cars on the road, what if we could harness mobile connectivity to reduce the hours we spend in congestion every year³⁰, connect cars in ways that save as many lives as the introduction of seat belts,³¹ and enable truck fleets to find quicker routes, perform real time engine diagnostics, and identify unsafe driving habits before they become a problem³²?
- **Reducing energy consumption and improving the environment.** As demand for goods and energy is on the rise, what if we could use mobile innovation to reduce the amount of energy we use, cutting our home heating and cooling costs by as much as 20% by letting our mobile devices tell our homes to turn down the thermostats when we are away³³, use two way mobile video conferencing to dramatically reduce the need for physical trips to make meetings in person, use mobile apps to compete with our neighbors for lowest energy use³⁴, and use a sea of connected sensors to radically reduce greenhouse gas emissions by as much as 25%³⁵?
- **From farm to fork, helping farmers produce more food with fewer resources.** With the amount of farmland shrinking but the number of mouths growing,³⁶ what if we could use precision agriculture and mobile broadband networks to connect farmers with data from

satellites, sensors and tractors to make better decisions that reduce chemical use, increase yields, decrease costs, reduce water consumption and feed more people?^{37 38}

- **Helping governments do more with less.** At a time when governments can't expand already tight budgets, what if they could expand their capabilities by harnessing mobile broadband to boost government efficiency³⁹; provide new and better kinds of services; reduce fraud and crime; and generally make smarter and more informed decisions?⁴⁰
- **Extending economic opportunity to more Americans.** At a time when many communities feel disenfranchised and disconnected, how can we use mobile to break down barriers, give more people a voice, and ensure that every child, regardless of where they live or how much their parents make, can access the same universe of knowledge in the palm of their hands?

These are but a few of the questions that innovators already are asking and policymakers should be asking more how they can constructively encourage and help realize all of this promise. In many cases, the keys to answering these questions, and our ability to improve the world around us, lies in our ability to better harness wireless innovation and the coming deluge of connected devices in new and innovative ways. However to maximize the potential to harness these technologies to help solve national challenges throughout economic sectors, we need a national strategy that requires federal agencies to explore ways in which mobile innovation can be leveraged in their sectors – e.g HHS looking at gains to the health sector, USDA exploring ways the technologies could boost agricultural outcomes, and the Department of Energy looking at opportunities for energy savings. To unlock the kinds of opportunities that mobile innovation can deliver will take a focused national strategy and federal inter-agency effort designed to take advantage of the transformative technologies that mobile innovation, the Internet of Things, and mobile enabled data can deliver. And to harness new technologies to solve some of our oldest and most challenging policy needs will require vastly better networks with dramatically better capabilities that 5G will enable.

We will need networks that go faster, extend farther, penetrate deeper, and react quicker, enabling breakthrough devices that are smarter, better, more capable and cheaper.

To solve these policy challenges, we also need to solve tough technology challenges. To expand access and opportunity, our wireless networks will increasingly have to serve a multitude of purposes simultaneously – becoming the Swiss army knife of technology platforms.

These networks need to be flexible enough to enable us to overcome the challenges that we are trying to solve in population dense and data rich neighborhoods like New York City, which may be

different than the challenges in rural and remote Iowa, which are different than the solutions for fast moving latency sensitive connected cars, which are different than the affordability challenges in up and coming economies like India. Yet because these networks are built on global standards, and technology is made more affordable when it takes advantage of the economies of scale made possible by the “build once, sell globally” technology model, we need network solutions that are flexible and robust enough to meet all of our future needs – many that remain unknown.

There is a growing consensus that to unlock future wireless opportunity, we will need mobile networks that can go even faster, flow even farther and penetrate even deeper; networks that are more ubiquitous and resilient; and that can enable new innovative solutions that respond faster, and that can conserve power to extend battery life to enable the growing sea of connected devices. To enable ubiquitous ultra-fast wireless networks that are capable in these ways, we need to rethink network architecture itself.

Tomorrow’s 5G opportunities will require networks that:

- **Offer speeds 100 times faster than today’s superfast speeds:** With mobile traffic worldwide doubling each year⁴¹, consumers will likely need networks capable of delivering speeds of 1 Gigabit per second by 2020, 10 Gigabits per second by 2025 and 1 terabit per second by 2030 – more than 65,000 times faster than the current 4G average of 15 megabits per second. Consumers will need speeds that enable ultra-high definition visual communications, immersive multimedia communication and entertainment; and support high-resolution sensors that require real-time communications with cloud services to process the data.⁴²
- **Support billions of simultaneously connected devices:** The next big thing won’t be one thing or even 1,000 things – it could be as many as 50 billion connected things by 2020, and several times more when 5G network deployment is in full swing in 2025. But today, only 1 percent of the things that can be connected already are. While today’s networks support more than 10 billion devices, to take full advantage of the Internet of Things we will need networks that can connect tens of billions more – each often with different networks needs than the next.⁴³

The Five G’s of 5G

1. **Gigabit Speeds** – Enable data rates of 10Gbps or higher
2. **Gigahertz frequencies** – Capable of using frequencies above 6 GHz
3. **Greater flexibility** – Enable networks to rapidly adapt to a broader range of requirements and demands
4. **Gee whiz Gizmos and Gadgets** – Will help drive M2M opportunities and connect billions of new devices
5. **Global competition** – There is a global race for wireless leadership already underway which will determine who will drive the global opportunity and reap its rewards

We will need networks capable of connecting more than 1 million devices per square mile, and more than 100 billion devices globally.⁴⁴

- **React 10 times more quickly:** To solve more demanding problems that require devices to respond to each other more quickly requires lowering what engineers refer to as the latency rate – the time it takes for devices to communicate with each other. Tomorrow’s networks will need latency rates 10 times lower than today’s 4G networks - enabling sub-millisecond latencies to control things with more precision and enable real-time connected controls including vehicle-to-vehicle communications. If we can drive latency lower, we can enable and control new kinds of applications built around immediacy; wirelessly control mission critical industrial machines, and unlock more opportunities for the way people interact with technology too.⁴⁵
- **Enable high performance applications with exceptional network reliability:** To fully enable this wireless future, we need to move past dropped calls, lost packets and uncertain call reliability. We will need wireless networks with 99.999% uptime. Extremely reliable networks will be essential for high performance applications, enabling mission critical applications, and new public safety opportunities.
- **Seamlessly switch between spectrum bands and networks on the fly:** Because tomorrow’s 5G networks will be made up of and utilize lots of different spectrum bands and networks simultaneously, we will need technologies that enable devices to instantaneously switch between the networks to enable seamless communications without missing a beat.
- **Reduce energy-per-bit power consumption by a factor of 1,000:** Long battery life is useful for smartphone users, but it is even more important for the billions of connected device applications that may need to run for as long as 10 years without a battery replacement or charge. Experts suggest new networks will need to continue to reduce the energy-per-bit usage by a factor of 1,000 to improve connected device battery life, enable devices that are smaller and cheaper, and devices that can be left alone for years at a time.

These technologies could help further mobilize America. With computer firepower rising, connectivity becoming more pervasive and the power of connectivity increasing, wireless gains mean we can extend boundless opportunity almost everywhere. But to handle the enormous diversity of types of applications that can be foreseen, 5G networks will face significant design challenges to be able to meet all of these needs at once.

5G networks will need to take advantage of:

- ***More spectrum.*** We will need to look both high and low for the additional spectrum that will be necessary to meet consumers continuing demand for greater bandwidth and faster speeds – particularly spectrum below 6 GHz where the earliest forms of 5G will occur. Clearing and reallocating low- and mid- band spectrum for commercial wireless use continues to be the essential ingredient for achieving and assuring continued wireless gains. It will take an all-of-

the-above approach to spectrum that leverages 4G bands, acknowledges the vast benefits from unlicensed Wi-Fi technologies, embraces sharing, but still takes the pragmatic steps to clear more government spectrum for licensed use.

- **Use of higher frequencies above 6 GHz.** Down the road, 5G technologies will be able to take advantage of high frequency bands including perhaps those above 24 GHz known as millimeter wave frequencies that can communicate at higher data rates over shorter distances. While the propagation characteristics of these high frequency bands can help enhance the density and capacity of networks, there are many technical issues yet to be solved.⁴⁶ However, because we need an all of the above approach to meet future wireless needs, clever technologists are discovering that such high frequencies may be more usable than once thought. To overcome the challenges with these high frequencies, they are working on highly directional antennas and steerable antenna beams that can track and acquire multiple reflected signals and compensate for the high propagation loss. To take advantage of these higher frequencies, the FCC has already issued a Notice of Inquiry on the Use of Spectrum Bands above 24 GHz for Mobile Radio Services. Likewise, the World Radio Conference 2019 standards release is expected to include higher frequencies bands.
- **Antenna arrays of 64 or more elements.** New types of antenna arrays will help steer and focus communications between specific devices, but may require major network architectural changes. 5G networks will take advantage of multiple input, multiple output (MIMO) technology, which multiplies capacity by transmitting different signals over multiple antennas. That can translate into better data rates for users. And with many antennas, beam forming becomes possible to direct communications toward the equipment that is meant to receive it.

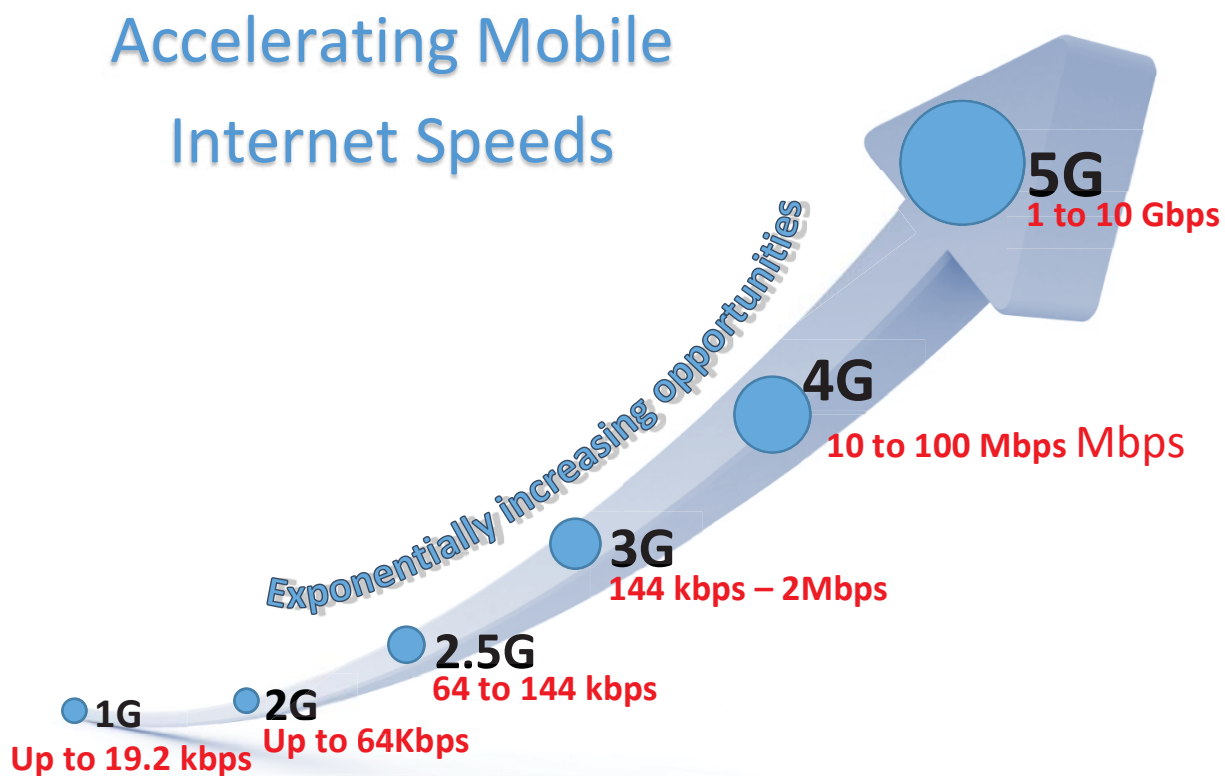
"Although existing efforts will almost double the amount of spectrum available for wireless broadband, we must make available even more spectrum and create new avenues for wireless innovation"

-- President Barack Obama
- **Ultra dense networks.** We are already seeing a trend toward network densification, which will continue through the use of smaller and smaller cells. It reduces the distance between transmitter and receiver, and enables shorter distance frequencies. Making denser networks a reality requires more fiber back haul, more flexible wireless tower citing rules, continued affordable access to poles and rights of ways, and massive new investments in network upgrades.
- **Simultaneous multiple connections.** Simultaneous connections across multiple technologies and frequencies can help improve wireless throughput. When we think of 3G or 4G, we think of a single transmission technology. The 5G world is likely to be multi-lingual -- seamlessly fusing 4G with 5G with Wi-Fi and new cell technologies to enable data to be transferred through multiple streams simultaneously.

- **Native M2M support.** 5G standards are being developed with flexibility in mind to enable massive numbers of connected devices, with highly reliable connections, low-power consumption, and low-latency for real-time operation.

The Biggest 5G Challenge is Achieving Bandwidth Gains

Already, 4G networks provide consumers with speeds 12,000 times faster than 2G networks.⁴⁷ And with consumer data appetites ever expanding, and new kinds of devices creating and gobbling up massive amounts of new data, bandwidth expansion has become a central focus for mobile network improvements. Already, mobile traffic worldwide is doubling approximately each year. It's a sign for how mobility is growing opportunity.



5G Status

5G technology is very much in the early development stages, and likely won't begin to be deployed comprehensively until 2020. Between now and 2016, the basic research on possible technologies to include in the standards will take place. Then between 2016 and 2018, the global standards bodies

will develop the primary standards. Between 2018 and 2020, major product development efforts will get underway, with early 5G deployments likely to occur around 2020. The combination of global standards, globally harmonized spectrum, and a more uniform regulatory approach will help promote timely availability of 5G globally.

But there is a lot happening between now and when 5G networks will first be deployed that will require continuous attention to improving today's 4G networks. For example between now and 2019, global mobile data traffic will increase 10-fold – growing three times faster than fixed Internet traffic.⁴⁸ Along the way, traffic from wireless and mobile devices will exceed traffic from wired devices.

By 2020, an estimated one in five vehicles worldwide will have some form of wireless network connection.⁴⁹ And by 2024, when 5G network rollout will be well under way, mobile networks are predicted to see machine-to-machine (M2M) connections jump 10-fold to 2.3 billion from 250 million in 2014 – half of which will be in cars.⁵⁰

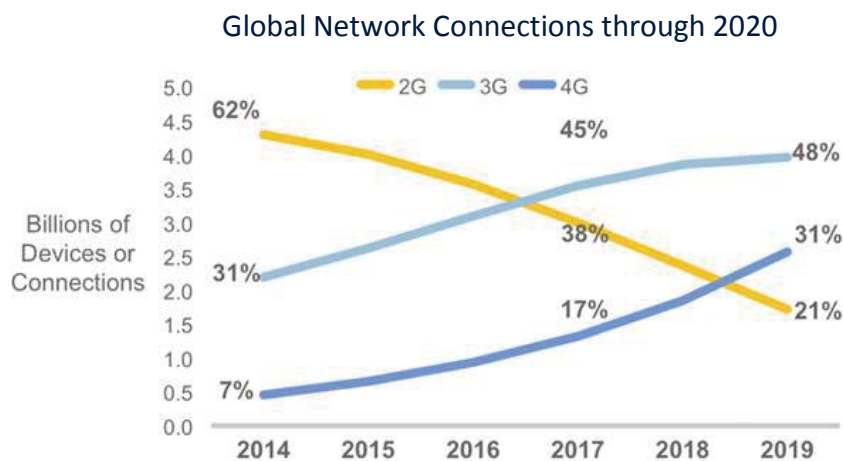
These amazing growth rates have already started, and will require that we continue to stay focused on 4G gains through the end of the decade. We will need to ensure that our 4G networks continue to be fast enough, secure enough, and reliable enough to support all of these new uses.

And we are still at the beginning of what 4G has to offer. Between today, and when the 5G networks of tomorrow will be fully deployed, there are innovative technologies that will continue to drive improvements to the networks.

- **LTE Advanced.** Major carriers have already announced their plans to roll out LTE Advanced technologies. LTE Advanced can stitch together streams of data from as many as five different frequencies – a trick known as “carrier aggregation” – to produce more capacity and faster speeds. Many expect LTE Advanced to achieve speeds of 1 Gbps, 10 times faster than today's LTE networks. LTE Advanced can also transmit and receive from as many as eight antennas, known as multiple-input, multiple-output, or MIMO, technology.
- **VoLTE.** Voice over LTE (VoLTE) and High-Definition Voice will finally enable high definition audio in mobile voice calls. It's not just better for business communications, it opens up a whole range of opportunities for the millions of Americans with hearing disabilities too⁵¹.
- **LTE Broadcast.** With video expected to account for about 70% of all mobile traffic by 2018,⁵² LTE Broadcast technologies can speed video to more users as the most efficient way to deliver the same content to a virtually unlimited number of users. It's great for live video events, streaming music, public safety communications and widely attended events. In addition, a new technology called LTE-Direct will enable direct device-to-device communications.
- **LTE-U/LAA and Wi-Fi.** Unlicensed wireless bands have played an enormous role in enabling a variety of communication technologies to co-exist and connect us in a multitude of ways. Indeed today, consumers send about 46% of their mobile data traffic over unlicensed Wi-Fi

networks.⁵³ Going forward, consumers are likely to need near zero-time switching between different spectrum technologies allowing seamless and high-speed communications across a broad range of technologies. To enable this future, we need to make sure that innovation can continue to thrive in the unlicensed bands by continuing the longstanding approach to technological neutrality and ensuring that technologies can co-exist by avoiding interfering with each other.

As a part of these further network improvements, many of the foundational technologies that will be needed for 5G will begin to be deployed in the next couple years to turbocharge today's networks and prepare for tomorrow's. For example, LTE Advanced technology will move us down the road on the carrier aggregation and MIMO technologies that will be at the heart of future 5G networks. At the same time, rather than moving to a new band as has happened when we have transition to a new generation wireless technologies in the past, 5G networks will continue to use and build upon the 4G spectrum and networks that are being deployed today.



Source: Cisco

Smarter Policies for Advancing Smarter Networks

As this smart revolution spreads from the wireless device in the palm of our hands to the smart watches, smart meters, smart cars, smart buildings, smart cities and smarter everything, smarter wireless policy becomes even more vital. With the future even closer than we think, it will take swift action and a bigger vision, with bolder action, for a brighter mobile broadband future. To get there,

policymakers need to develop a comprehensive national strategy to mobilize America and ensure U.S. leadership in the transition from 4G to 5G.

Mobilizing America: Five Key Steps to Accelerate 5G Opportunity

The U.S. needs to take pragmatic policy steps to ensure it continues to lead the world in the next generation of wireless.

1. **Develop a national action plan for mobilizing America to address some of our toughest policy challenges.**

While the national broadband plan made important strides in helping policymakers focus attention on the opportunities to solve some of our biggest challenges using high-speed networks, it's time for policymakers to develop a national mobile broadband strategy that can mobilize America. If we want to be 5G leaders, and harness these technologies to help solve some of our greatest national policy challenges – from accelerating transportation, reducing energy consumption, improving health care, strengthening public safety, to boosting manufacturing – then we need a comprehensive national strategy that not only looks at reducing the barriers to innovation, but that charts a course toward accelerating solutions to challenging problems throughout the country. Given that connected devices could be covered by as many as two-dozen agencies (each with different and perhaps conflicting regulatory approaches)⁵⁴, policymakers should create a uniform national strategy through an inter-agency task force, like the Broadband Opportunity Council, that is focused on agency by agency action for harnessing mobile innovation and the emergence of connected devices to help solve national policy challenges in every sector of the economy.⁵⁵ Doing so will help leapfrog the efforts of other countries.

2. **Accelerate access to the vital spectrum that enables blazing fast speeds.**

Every wireless transition from 1G to 4G has required new spectrum in order to expand opportunity. With

exponentially increasing spectrum demand, the most important policy enabler for achieving the vast benefits from this mobile revolution involves making more commercial spectrum available. Spectrum is the vital fuel that powers the benefits from both today's 4G LTE networks and

"This new era in global technology leadership will only happen if there is adequate spectrum available to support the forthcoming myriad of wireless devices, networks, and applications that can drive the new economy."

-- President Barack Obama

tomorrow's 5G networks. As we make the transition to a faster future, one thing we know for sure is that consumers will keep consuming ever increasing amounts of bandwidth, requiring ever expanding amounts of spectrum – the oxygen for mobile services. However, today, the U.S has the third lowest amount of spectrum available for LTE. Germany for example, has twenty-six times more spectrum dedicated per subscriber.⁵⁶ Because our 5G networks will be built upon our 4G networks, and because it can take from 6 to 13 years to free up government spectrum, lack of adequate spectrum today leaves us ill equipped to take advantage of this 5G future tomorrow.⁵⁷

The Administration has already taken some vital steps to advance this mobile future and help us regain mobile leadership after falling behind in 3G deployment.⁵⁸ Maintaining global leadership now depends upon the Administration's continued focus on freeing up the rest of the 500 MHz of spectrum that the administration has already committed to identifying and reallocating. Since it can take as long as seven years to free up a single spectrum band, and since we have no national plan for identifying spectrum beyond 2020, policy makers need to begin the long-term process of thinking through a longer term strategy for maximizing the national benefits that can come from the increasingly scarce spectrum availability. It will take an all of the above approach to spectrum that includes licensed, unlicensed and sharing models, but that is rooted in opportunities for clearing spectrum that can be licensed.

3. Lower barriers for innovation and investment.

To achieve 5G leadership, we need to continue to foster investment and innovation in a vibrant ecosystem of entrepreneurs, innovators and start-ups. With \$260 billion of private capital already invested in today's mobile networks, upgrading our networks for tomorrow will require thoughtful policy strategies and the removal of barriers to encourage the massive new investments that upgrading our networks to 5G will require. As Jason Furman, the Chair of the White House Council of Economic Advisor notes, "We also must recognize that investments in infrastructure depend critically on a stable, predictable and light touch regulatory regime."⁵⁹ In addition to fostering massive new investments, 5G leadership will take an accelerated tower siting process and access to more places to locate those antennas – like access to street lamp posts and telephone poles. It will take a comprehensive administration effort to facilitate the timely and efficient deployment of wireless broadband facilities on federal lands, buildings, and rights of way, federally assisted highways, and tribal lands.⁶⁰ It will take development of uniform federal contracts, applications, and permit terms to facilitate private sector access to federal properties.⁶¹

4. Crank up the innovation engine.

To continue to lead the world in wireless opportunity, the U.S. needs continued investments in the basic building blocks that enable innovation – in science, research and technology that lead to new discoveries, new features and continuously accelerating advances. Federal investments in basic research have been instrumental to the advancement of many of the fundamental technologies at the core of today's smartphones. Everything from the Internet connection,

lithium-ion batteries, the hard drive, the memory chips, the liquid crystal display, the browser, search engines and even Siri – have their roots in basic federally funded research.⁶²

However when it comes to 5G, other countries are already attempting to out-innovate us. European leaders have launched a \$1.8 billion 5G research effort in order to ensure it's a leader in shaping the 5G future.⁶³ South Korea kicked off its 5G research efforts in 2008, and intends to invest more than \$1.5 billion in 5G R&D, as part of an initiative to deploy commercial 5G services by 2020.⁶⁴ While in the U.S., the National Science Foundation has already funded some foundational research in key areas,⁶⁵ MIT researchers point out we now face a new and perplexing innovation gap whereby the U.S. is spending an ever-smaller share of its budget on basic research while other countries are on the rise.⁶⁶

In the U.S., federal spending on research as a share of total government outlays has fallen from nearly 10 percent in 1968, during the height of the space race, to only three percent in 2015. To move forward, we need to stoke the innovation bonfire with basic and targeted research that can propel wireless discovery and innovation. As other countries are investing heavily in an effort to pass us in the wireless fast lane, federal investments in basic research must be a part of the equation for out-innovating, out-competing, and winning the future.

5. Fill the talent pipeline with the innovators who can maximize 5G opportunity.

To capture the full economic potential from our mobile future, companies and policymakers must overcome a looming talent shortage. This next wave of innovation-led wireless benefits will require us to tap the talent and tenacity of our brightest workers. However today, we lack enough of the skilled workers we need to lead this future. Today there are roughly half a million job openings that have not been filled in information technology fields like software development, network administration and cybersecurity – many of which did not even exist just a decade ago.⁶⁷ Because these jobs pay higher than other private sector jobs, removing the barriers that allow people to receive the training and education they need can be one of the fastest paths to good paying high tech jobs in fast growth industries.

To create stronger talent pipelines that can sustain future needs, we need to help educate the next generation of network engineers, gee-whiz device developers and app designers – the doers and dreamers who will advance this revolution.

Wireless technologies themselves can be a powerful tool for helping to boost learning outcomes and engage more kids in STEM opportunities. Today any child with access to a smartphone, regardless of how much money their parents make or the zip code they live, can access the entire universe of human knowledge in the palm of their hands. Already 81 percent of teachers believe mobile devices enrich classroom education.⁶⁸ Mobile technologies and tablets are also the key for helping to bring about one-to-one learning opportunities that improve educational outcomes. That may be why 90 percent of students who are tablet owners say that these devices are valuable for educational purposes.⁶⁹ Advancing faster, better, cheaper mobile broadband tools can help connect the next generation of STEM leaders to this learning future faster.

Conclusion

The mobile revolution has only just begun. In every revolution there are opportunities – opportunities that are often seized only by those who can look beyond the horizon, recognize the opening, and chart a path that overcomes the barriers necessary for achieving a brighter future. Advancements in mobile technologies are not just be a vital spark for improving our lives and transforming the way we work; they can be an economic dynamo for creating the new jobs, industries and solutions that are essential for winning the future. However, to achieve these gains, we need to chart a future that ensures we continue to lead in 4G technologies as a platform for future leadership in 5G.

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⁴³ Cisco estimates that between now and 2019 (when 5G standards are developed) an additional 10.2 billion devices will go online, for a total of 24.4 billion devices.

⁴⁴ Rory Jones, "Telecom's Next Goal: Defining 5G," Wall Street Journal, (March 9, 2015), available at <http://www.wsj.com/articles/telecom-industry-bets-on-5g-1425895320>.

⁴⁵ Our ears can process communications with the kind of 100 millisecond delays that were common in 2G networks. However, our human eyes are more sensitive to delays. Anyone who has experienced motion sickness while trying out virtual reality headset can confirm that our eyes perceive mismatch between the motion we feel and the image we see of as little as 10 milliseconds. Some people are sensitive to lags of as little as 3.2 milliseconds. Achieving low latency is critical for enabling broad acceptance of virtual reality solutions that don't produce motion sickness, and for unlocking tactile interfaces which involve touch interfaces that may need response times of as low as one millisecond to succeed. Sarah Zhang, "The Neuroscience of Why Virtual Reality Still Sucks," Gizmodo, (March 18, 2015) available at <http://gizmodo.com/the-neuroscience-of-why-vr-still-sucks-1691909123>.

⁴⁶ In October 2014, the FCC launched a proceeding to study 5G and the potential for using millimeter wave spectrum above 24Ghz to compliment other bands to support 5G. While signals sub 3Ghz can travel many miles and penetrate

buildings, millimeter waves travel shorter distances, don't pass as easily through building walls, are weakened going through trees, can be absorbed by rain drops, and even human bodies can create shadow effects.

⁴⁷ "4G Networks 12,000x Faster than 2G," CTIA, (March 2, 2015), *available at* <http://www.ctia.org/resource-library/facts-and-infographics/archive/4g-networks>.

⁴⁸ According to Cisco's Visual Networking Index (VNI) Global Mobile Data Traffic Forecast Update, global mobile data traffic will increase nearly tenfold between 2014 and 2019. Mobile data traffic will grow at a compound annual growth rate (CAGR) of 57 percent from 2014 to 2019, reaching 24.3 exabytes per month by 2019. Global mobile data traffic will grow three times faster than fixed IP traffic from 2014 to 2019. *See*, http://www.cisco.com/c/en/us/solutions/collateral/service-provider/ip-ngn-ip-next-generation-network/white_paper_c11-481360.html.

⁴⁹ Eric Auchard, "Not so fast: connected cars could cause data traffic jams," Reuters, (May 21, 2015), *available at* <http://www.reuters.com/article/2015/05/21/us-autos-connected-data-idUSKBN00616M20150521>.

⁵⁰ Eric Auchard, "Not so fast: connected cars could cause data traffic jams," Reuters, (May 21, 2015), *available at* <http://www.reuters.com/article/2015/05/21/us-autos-connected-data-idUSKBN00616M20150521>.

⁵¹ Two-thirds of the frequencies in which the human ear is most sensitive, and 80 percent of the frequencies in which speech occurs, are beyond the capabilities of traditional phone network capabilities. The PSTN was designed to use only G.711 digital voice which is a frequency bandwidth of 300 Hz to 3400 Hz. However a "wideband" codec can have a frequency responses of 150 Hz to 6800 Hz (basically one extra octave on both the low end and the high end). High Definition voice capabilities have the potential to improve voice intelligibility through CD quality sound – which can be especially impactful for people with hearing limitations. "Benefits of VOIP," Von Coalition, *available at* http://www.von.org/secpgs/02_benefits/benefits_06_disabilities.html.

⁵² Cisco VNI Mobile report

⁵³ Globally, 46 percent of total mobile data traffic was offloaded onto the fixed network through Wi-Fi or femtocell in 2014. In 2014, 2.2 exabytes of mobile data traffic were offloaded onto the fixed network each month. *See*, http://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/white_paper_c11-520862.html.

⁵⁴ Internet of things could be covered by at least two dozen agencies from the Food and Drug Administration to the National Highway Traffic Safety Administration, from aviation to agriculture – each often exploring different regulatory approaches. Darren Samuelsohn, "What Washington really knows about the Internet of Things," Politico, *available at* http://www.politico.com/agenda/story/2015/06/internet-of-things-caucus-legislation-regulation-000086?hp=t2_r.

⁵⁵ The White House charted NSTAC have also recommended, the government should "Create an IoT interagency task force that coordinates with existing organizational bodies to foster balanced perspectives between security, economic benefits, and potential risks." "NSTAC Report to the President on the Internet of Things," NSTAC, (Nov. 19, 2014), *available at* <http://www.dhs.gov/sites/default/files/publications/NSTAC%20Report%20to%20the%20President%20on%20the%20Internet%20of%20Things%20Nov%202014%20%28updat%20%20%20.pdf>.

⁵⁶ Meredith Attwell Baker, "President & CEO, CTIA-The Wireless Association Remarks," CTIA, (May 14, 2015), *available at* <http://www.ctia.org/docs/default-source/default-document-library/isart-speech-public.pdf>.

⁵⁷ According to the FCC's National Broadband plan, the process of revisiting or revising spectrum allocations has historically taken 6-13 years, (Table 5-C: Time Historically Required To Reallocate Spectrum), *available at* <http://www.broadband.gov/plan/5-spectrum/>.

⁵⁸ In 2010, the White House announced a 10-year strategy for doubling the amount of commercially available spectrum – freeing up another 500 MHz of spectrum for commercial use by 2020.

⁵⁹ Furman says, "Catalyzing investment in mobile broadband is especially important given the collision of our use of technology with the laws of physics." But he also notes, "We also must recognize that investments in infrastructure depend critically on a stable, predictable and light touch regulatory regime." Jason Furman, "Total Factor Productivity and Telecommunications: Policy Ingredients for Shared Growth," AEI's Center on Internet, Communications and Technology Policy, (Sept. 17, 2013), *available at* https://www.whitehouse.gov/sites/default/files/docs/aei_if_telecom_9.17.13.pdf.

⁶⁰ “Presidential Executive Order on Accelerating Broadband Infrastructure Deployment,” Office of the Press Secretary, White House, (June 14, 2012) *available at* <https://www.whitehouse.gov/the-press-office/2012/06/14/executive-order-accelerating-broadband-infrastructure-deployment>.

⁶¹ Interagency Working group report on Progress on Accelerating Broadband Infrastructure Deployment. “Implementing Executive Order 13616 Progress on Accelerating Broadband Infrastructure Deployment, Broadband Deployment on Federal Property Working Group, (Aug. 2013), *available at* https://www.whitehouse.gov/sites/default/files/microsites/ostp/broadband_eo_implementation.pdf.

⁶² The iPhone 4S Siri technology is a direct outgrowth of a federally-funded research project called the “Personalized Assistant that Learns” at the Defense Advanced Research Projects Agency (DARPA), according to the White House. Tom Kalil and Kumar Garg, “Applying iPhone Innovation to Better Schools and Cleaner Energy,” White House Blog, (Oct. 17, 2011), *available at* <http://www.whitehouse.gov/blog/2011/10/17/applying-iphone-innovation-better-schools-and-cleaner-energy>.

⁶³ Rick Merritt, “5G Dials Up Global Efforts,” EE Times, (Dec. 24, 2013), *available at* http://www.eetimes.com/document.asp?doc_id=1320491.

⁶⁴ Tony Fleet, “Evaluating the Emerging \$5 Billion 5G Wireless Opportunity,” MarketResearch.com, (Feb. 25, 2015), *available at* <http://blog.marketresearch.com/evaluating-the-emerging-5-billion-5g-wireless-opportunity>.

⁶⁵ For example around millimeter wave networks at 60 GHz, extreme densification, delay-tolerant networking for more robustness, multi-path solutions, inherent security architectures, and better digital signal processing technologies.

⁶⁶ Robert McMillan, “U.S. Is Faulted for Risking Edge in R&D,” Wall Street Journal, (April 27, 2015), *available at* <http://www.wsj.com/articles/mit-warns-u-s-may-be-losing-r-d-lead-1430170741?mod=LS1>.

⁶⁷ “FACT SHEET: President Obama Launches New TechHire Initiative,” Office of the Press Secretary, White House, (March 9, 2015), *available at* <https://www.whitehouse.gov/the-press-office/2015/03/09/fact-sheet-president-obama-launches-new-techhire-initiative>.

⁶⁸ Gayle Bennett, “Tablets rewrite the classroom rules,” USA Today, (June 23, 2014), *available at* <http://www.usatoday.com/story/sponsor-story/dell/2014/04/28/dell-tablets-in-education/8420627/>

⁶⁹ Pearson Foundation, Survey on Students and Tablets 2012, *available at* http://www.harrisinteractive.com/vault/Pearson%20Tablet_FINAL_3-14-12.pdf